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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (14): 2621-2627, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.2621.2627

A General Automatic Scoring Framework for Chemical Simulation Process

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Abstract: In recent years, simulation technology has been widely used for operator training, experiments and research of control strategy in chemical process. However it is difficult to evaluate the results of operator training, experiments and research. A general automatic scoring framework is proposed for chemical simulation process. In the framework, chemical simulation process is divided into five aspects: Operation, quality, safety, consumption, production. In the aspects, the results of operator training, experiments and research can be evaluated and scored automatically. Basing on the framework, an automatic scoring system is designed and developed. The system is developed as a Dynamic Link Library (DLL) and can supply automatic scoring for various chemical simulation systems.

Key words: General, chemical simulation process, scoring framework, automatic scoring system

INTRODUCTION

Chemical process is one of pillar industries in china and is very important for national economy. Due to complexity and high risk it is nearly impossible to carry out operator training, education and research of chemical process in the real chemical plants or using the real chemical equipments. As the development of computer technology, computer simulation of chemical process became popular in operator training, education and research.

Due to real industrial background, high-accuracy, high flexibility, safety, low cost and so on, chemical simulation systems have been widely used in training, experiments and research. Simulation technology first was used for operator training (Wu *et al*., 1993; Drozdowicz *et al*., 1987; Melli *et al*., 1987; Zheng and Furimsky, 2003; Zou *et al*., 2005). As the development of simulation technology, simulation has been applied in education and research of chemical process (Xia *et al*., 2003; Wu, 2005). At the same time, internet technology is used in simulation (Yu *et al*., 2004). Several scoring systems for chemical simulation processes have been proposed to evaluate the result of training, education and research (Li *et al*., 1999; Yu *et al*., 2007; Ma *et al*., 2012). However, the current scoring systems focus their own aspects, such as operation, alarm and so on. Different scoring rules are used in the systems. There is no a general scoring system covering all the aspects in chemical process. Actually, automatic scoring is a very efficient approach for evaluation of training, education, research. An excellent scoring system can reduce human work and improve efficiency. More importantly, scoring objectivity and fairness can be achieved using the scoring system. The quality of training, education and research can be improved.

Due to the exiting problems above, a general scoring framework is proposed. In which, chemical process operation, quality, safety, consumption, production and so on can be evaluated. Basing on the framework, an automatic scoring system is designed and developed. It can supply automatic scoring for operator training, experiments and research in various chemical simulation systems. Its application on reboiler process showed that the system can evaluate the result and process for operator training, education and research efficiently.

The structure of the paper is as follows: Introduction is shown in the first part. In the second part, the general scoring framework is introduced. Basing on the framework, an automatic scoring system is designed and developed in the third part. An application is shown in the fourth part. The conclusion is discussed in the fifth part.

GENERAL SCORING FRAMEWORK

An ideal scoring framework: An ideal scoring framework should own the characteristics which are shown in Fig. 1.

Generality: It means that the framework can be used for different processes and equipments.

Comprehensiveness: It means that the framework can evaluate different aspects in chemical process. It should include basic aspects in chemical process at least.

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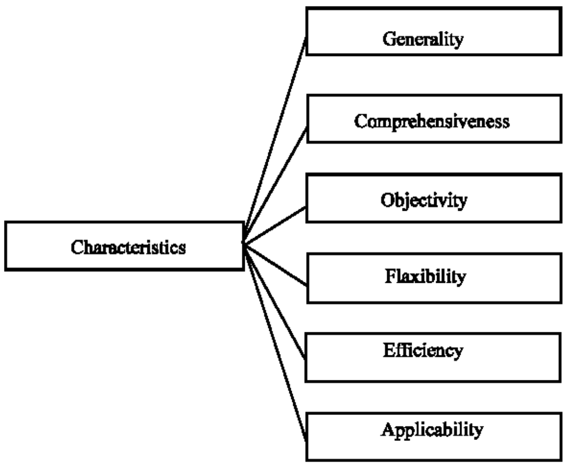

Fig. 1: Characteristics of an ideal scoring framework

Objectivity: The framework should work objectively and scoring rules should be set objectively.

Flexibility: The rules can be set flexibly in the framework.

Efficiency: Algorithm in the framework should be executed efficiently.

Applicability: Framework should be applicable for operator training, education and research in the chemical simulation process.

An ideal or excellent scoring framework should have the above characteristics. However, up to now, there is no a scoring system can obtain all the characteristics.

A general scoring framework for chemical simulaiton process.

According to the characteristics the scoring framework should own above, a general scoring framework is designed.

The scoring aspects in the framework: In order to evaluate in the chemical simulation process comprehensively, such as operation, quality of control loops, production and so on, the aspects used in the framework are shown in Fig. 2.

As it shown in Fig. 2, the left one is the structure of a real chemical plant. It includes production equipments, measurement\actuating equipments, operation, communication network, control system, SIS (safety instrument system) system and management.

According to the real plant, the scoring aspects are summarized as operation, quality, safety, consumption, production. The five aspects can basically include the important aspects needed to be evaluated for operator training, education and research in chemical simulation process.

Operation: Operation is a very important issue for operator training. Operation needs to be evaluated during start-up process, stop process, fault maintenance.

In order to evaluate an operation comprehensively it is divided into four parts: sequence condition, chemical condition, action and target. Sequence condition means that an operation needs to be executed according to the sequence. Chemical condition means that an operation needs to be executed when the chemical condition is satisfied. It includes steady condition (level of tank = 50 for example) and dynamic condition (level of tank increasing radio = 2 for example).

Action means that an operation should be executed exactly (open a valve to 50% for example). The target means that the target should be satisfied when the action is executed. An operation can be finished until all the four parts are satisfied.

Quality: Quality is an aspect which is used to evaluate performance of control loops. It includes: whether the controlled variable is steady and the curve after disturbance is added. When a disturbance is added, some parameters are calculated for evaluating the performance of control loops, such as decaying ratio, maximum deviation and so on.

Safety: Safety is an important issue for chemical simulation process. It evaluates whether some important variables have been in dangerous state (over the high alarming limits or below the low alarming limits).

Production: Production is used to evaluate the final production of the simulation process.

Consumption: Consumption is used to evaluate the usage of raw material and energy.

The whole structure of the framework is shown in Fig. 3.

Scoring strategy: In the framework three kinds of scoring strategies are used.

Positive strategy: This means if a rule (operation, quality and etc.) is satisfied, the score of the rule can be gotten. Otherwise, the score of the rule is set to be zero.

Negative strategy: This means if a rule (safety and etc) is satisfied, zero is gotten. Otherwise, deduction will be used.

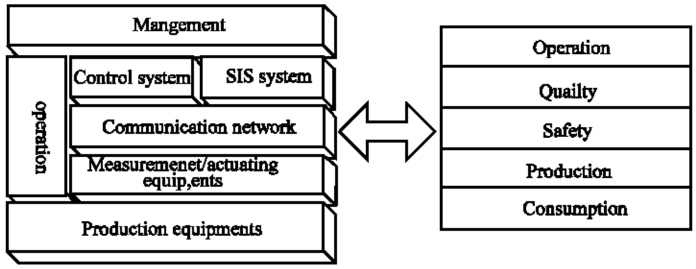

Fig. 2: Scoring aspects of framework

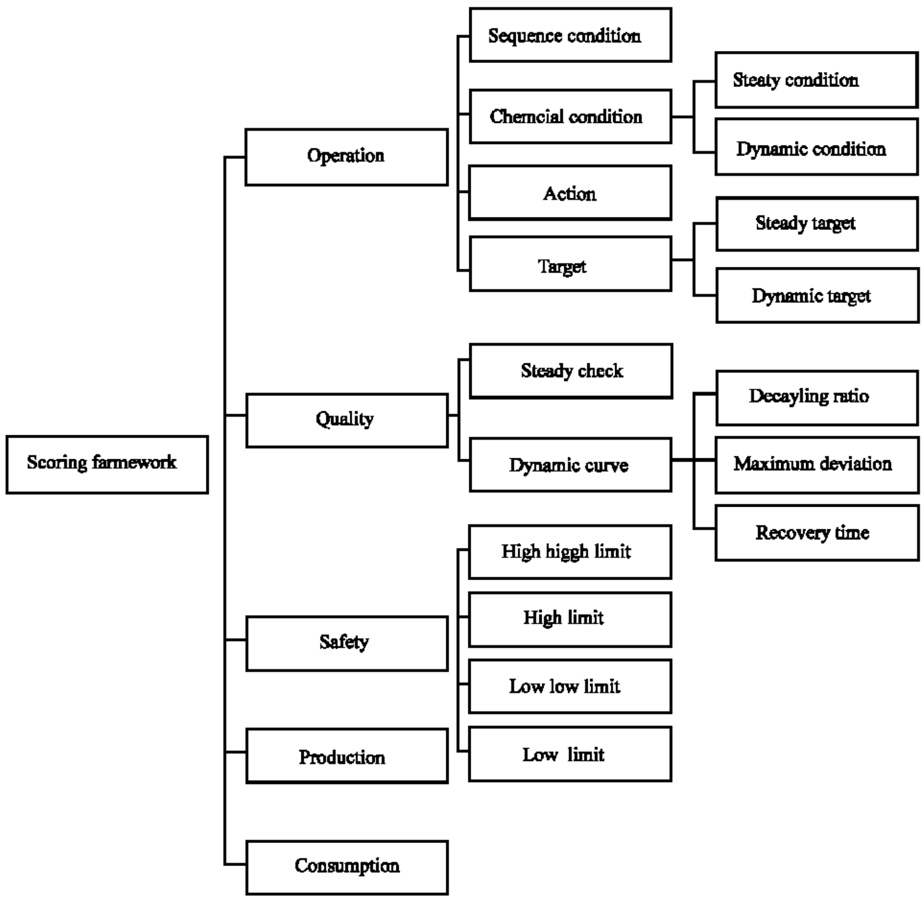

Fig. 3: Structure of framework

Safety strategy: This means that if a dangerous condition occurs, the total score will be zero.

The three strategies can be used according to different rules and situation.

ALGORITHM OF SCORING FRAMEWORK

The algorithm is as follows:

- Rules configuration. Different rules are set according to the five aspects above mentioned
- Operation monitoring and scoring. If an operation is detected, an inference engine is used to determine whether the sequence and chemical condition are satisfied. If satisfied, the score of the conditions are gotten and the engine is to decide whether the action and target are finished. Otherwise, no score is gotten and waiting for next operation. If the action and target are finished, the score of action and target are gotten. Otherwise, waiting for the finish of action and target

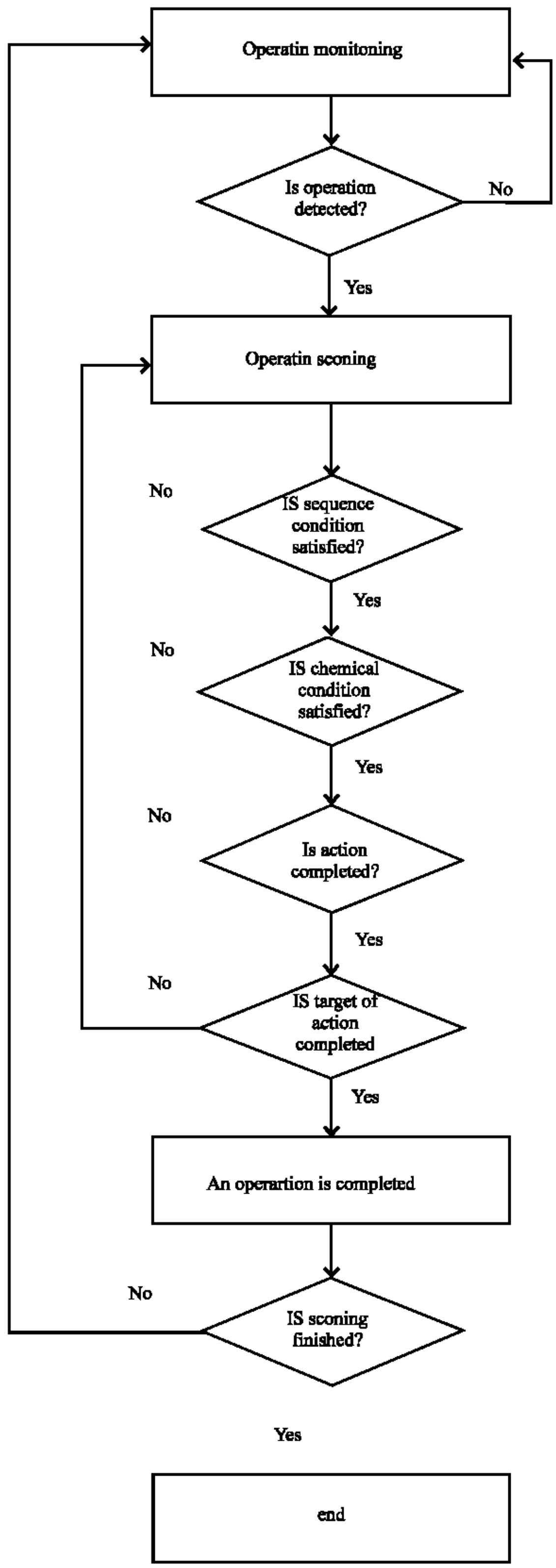

Fig. 4: Operation monitoring and scoring

- Safety monitoring. During operation monitoring, the safety monitoring is executed at the same time. It is used to monitor whether variables are over and below the limits
- Calculating the score when the scoring process ends. Operation score has been calculated during scoring process. Quality score is calculated according to whether the variables are steady and the parameters such as decaying ratio, maximum deviation and recovery time. Safety score is calculated according to whether the variables in the rules are over limits. Production and consumption score are calculated according to production and consumption. Finally the total score is obtained

The flowchart of operation monitoring and scoring is shown in Fig. 4.

The flowchart of quality scoring, safety scoring, production scoring and consumption scoring are shown in Fig. 5.

AUTOMATIC SCORING SYSTEM

Based on the framework, an automatic scoring system is designed and developed. The system is designed and developed according to object-oriented technique. The system is developed as a DLL (dynamic linking library) and can be used for other chemical simulation system.

The class model is shown in Fig. 6.

The interface of rules configuration in the system is shown in Fig. 7.

As it shown in Fig.7, operation, quality (control loops), safety, production and consumption can be evaluated by setting different rules.

CASE STUDY

In this part, the scoring system is used to set rules and score for the reboiler process. Its process is shown in Fig. 8.

Take start-up process for example, the rules are set in Table 1, 2 and 3.

As it shown in Table 1, there are four steps in the start-up process, every step includes sequence condition, chemical condition, action and target four parts. The score for every step is 5 and the strategy is positive. The quality rule is set in Table 2. Steady value, high limit and low limit are needed to calculate whether the variable is steady. The safety rules, consumption rules and production rules are shown in Table 3. The strategy of safety is negative. It means that once the variables are over or below the high or low limit, the deduction will be used. Because if

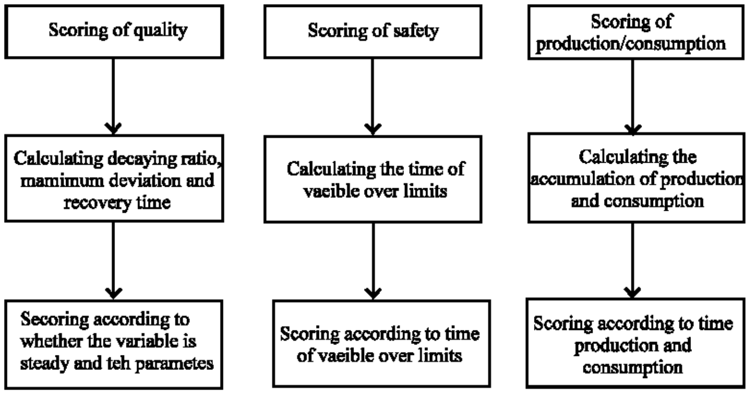

Fig. 5: Flowchart of quality scoring, safety scoring, production scoring and consumption scoring

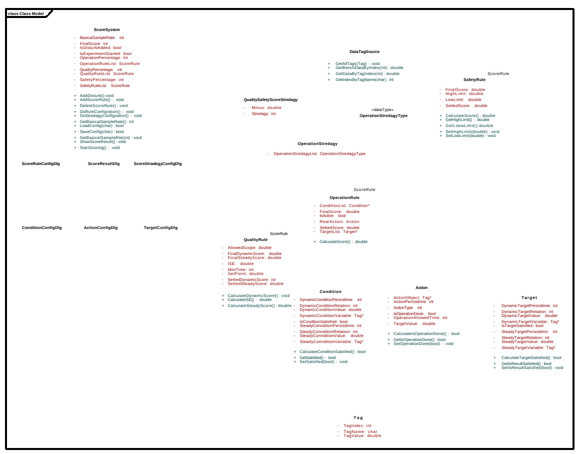

Fig. 6: Class model of the system

Fig. 7: Rule configuration interface

the variables in the safety rules are beyond the limits, accident may occur, so negative strategy is used.

The reboiler simulation process is started and the scoring system starts to work. When the start-up process ends, the scoring result is shown in Table 4.

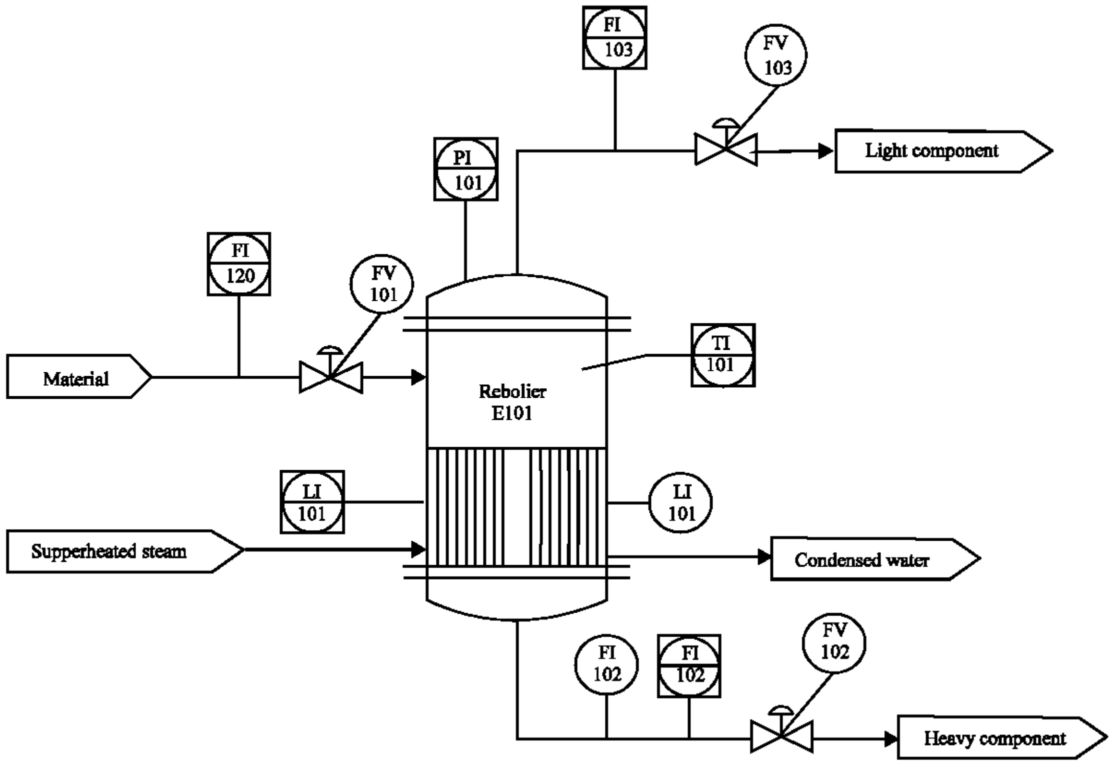

Fig. 8: Rreboiler process

Table 1: Operation rules

Condition	Action	Target	Score	Strategy
	OpenV101	L101= 50	5	Positive
L101 = 50	OpenV105	T101=112	5	Positive
T101 = 112	-	A101=11	5	Positive
A101 = 11	OpenV102	F102=12	5	Positive

Table 2: Quality rules

	Steady value	High limit	Low limit	Score	Strategy
T101	112	113	111	30	Positive
A101	11	11.5	10.5	30	Positive

Table 3: Safety, consumption and production rules

	High limit	Low limit	Score	Strategy
Safety				
L101	80	30	5	Negative
T101	200	103	5	Negative
Consumption				
F105	6200	550	10	Positive
Production				
F102	19200	9600	10	Positive

As it shown in Table 4, operation, quality, safety, consumption and production are evaluated by the system. The scores of quality are calculated according to recovery time, maximum deviation, decaying ratio.

Table 4: Scoring result

	Operation				
		Sequence condition	Chemical Action	Target	Score
1	finished	finished	finished	finished	5
2	finished	finished	finished	finished	5
3	finished	finished	finished	finished	5
4	finished	finished	finished	finished	5
	Quality				
	Recovery time	Maximum deviation	Decaying ratio	Steady	Score
T101	115	4.5	3.1	yes	30
A101	96	2.5	1.8	yes	30
	Safety				
	High limit	Low limit	Beyond the limits		Score
L101	80	30	no		0
T101	200	103	no		0
	Consumption				
	High limit	Low limit	Consumption		Score
F105	6200	550	1640		6.4
	Production				
	High limit	Low limit	Production		Score
F102	19200	9600	13400		7.5
No.			Total		93.9

CONCLUSION

Due to the difficulty in evaluating the result of operator training, education and research in chemical simulation systems, a general automatic scoring framework is proposed. The framework includes five scoring aspects: operation, quality, safety, production and consumption. A scoring system is designed and developed according to object-oriented technique.

The application on scoring for a reboiler process proved that the system can evaluate and score for chemical simulation process comprehensively, objectively and effectively in operation, quality, safety, consumption, production and so on. It can be used for operator training, education and research in any other chemical simulation systems.

ACKNOWLEDGMENT

This paper is supported by the the Fundamental Research Funds for the Central Universities.

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